FUSION MATERIALS

ALL-PURPOSE ACCELERATOR

One of the most challenging aspects of fusion engineering is materials development. The energetic neutrons produced by fusion reactions can cause transmutations, heating, and radiation damage in conventional materials.

As part of a program to develop and test materials for fusion, a new concept for a particle accelerator was evaluated, modeled, and constructed. The radio-frequency quadrupole (RFQ) linear accelerator has since evolved into an attractive means of producing ion beams, with extensive applications in high-energy physics research, defense, manufacturing, materials, and health and medicine. It is also being studied as a heating system for future fusion reactors.

The deuterium-tritium (D-T) reaction, which will probably be used by the first fusion reactors, produces intense neutrons, with energies of 14 million electron volts (MeV). To accurately determine the material damage caused by these neutrons, and to develop materials that can resist this damage, fusion scientists have had to find ways of producing a neutron radiation environment similar to that resulting from the D-T fusion reaction.

Particle accelerators increase the kinetic energy of charged particles or ions by accelerating them in an electric field. In a linear accelerator, or linac, the particles are created by a plasma discharge, formed into a beam, and then accelerated through a straight evacuated chamber to bombard a target. By changing the beam energy and the target material, accelerator physicists can create and study a variety of effects. The interaction of the beam and the target can produce the desired neutron radiation for materials testing.

Until 1970, linacs were very large structures that could not efficiently maintain a coherent beam at low kinetic energies. Then a concept was developed in Russia for a linac that uses radio-frequency (rf) voltages to create the electric field for accelerating the particles and quadrupole magnetic fields to focus the beam.

Along its central axis, the rf quadrupole, or RFQ, produces complex, varying electric fields that convert the incoming ion stream into "bunches" of ions. The fields also keep the bunches together while accelerating them.

The photograph at left shows a conventional linac and an RFQ linac (on the table). In addition to being much smaller, the RFQ linac is simple and reliable. It was soon recognized as a useful device that could accept large quantities of low-energy ions and accelerate them to much higher energies. Development